Automation Solutions for Analytical Measurements
Automation Solutions for Analytical Measurements

Concepts and Applications

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Preface

Automation systems with applied robotics have already been established in industrial applications for many years. In the field of life sciences, a comparable high level of automation can be found in the areas of bioscreening as well as high-throughput screening. Strong deficits still exist in the development of flexible and universal fully automated systems in the field of analytical measurements. Reasons are the heterogenous processes with complex structures, which include sample preparation and transport, analytical measurements using complex sensor systems as well as suitable data analysis and evaluation. Furthermore, the use of non-standard sample vessels with various shapes and volumes results in an increased complexity. The state of the art includes automated workstations, semi-automated systems, or proprietary fully automated systems, which have been developed for specific applications. In general, a flexible use of automation systems for different applications is a challenging scientific task.

The development of appropriate automation systems in the field of analytical measurements using analytical instruments and complex sensor systems initially requires a systematic analysis of the processes to be automated with the aim to develop suitable structures and allocate them to these processes. In industrial applications, eight different structures can be distinguished according to their centralized or decentralized process structure, local, and functional structure. In analytical measurement technology, there are limitations regarding a general applicability of these structures, thus, an adequate adaption is required. Analytical processes are always characterized by a decentralized process structure. This enables a distinction according to their local and applicative structure. Depending on the robot technology used, two basic automation concepts can be applied to processes in analytical measurements: central system integrators and flexible robots. For a maximum versatility of the processes to be automated an extension to a third concept – integrated robotics – is possible.

Due to their high flexibility, robots can be used as transport systems. This enables a connection of the individual subprocesses and workstations, whereby the robot has the function of a central system integrator. A higher flexibility of an automation system can be achieved when, besides transportation tasks, the robot additionally performs active manipulation tasks, whereby the robot has
the function of a flexible robot. A further increase in flexibility can be achieved using mobile robots, which perform both, transportation tasks between various subsystems and manipulation tasks. For an efficient workload of such robots, some of these tasks can be performed even during the transport.

This book will provide a substantial contribution to the development and systematization of appropriate automation systems in the life sciences, in particular, in the field of analytical measurement technique. The first chapter gives a widespread overview about the history and the impact of automation systems in the field of life sciences. The second chapter involves a critical review of existing automation systems in bioscreening, chemical sciences, and analytical measurement applications. The chapter begins with general definitions and basics and concludes with the requirements for automating analytical measurement processes. The third chapter is particularly dedicated to the theoretical view on automation structures and presents general automation concepts for analytical measurement processes. The theoretical considerations are completed with delineations regarding the degree of automation and statistical evaluations. The fourth and fifth chapters present realized automation concepts with a central system integrator and a flexible robot. Therefore, special applications from various areas are introduced. This includes applications in environmental measuring technology, medicine, drug development, and drug discovery as well as quality assurance. The goal is to achieve a high degree of automation with maximum sample throughput, short processing, and measurement times with a special focus on the applicative flexibility of the automated systems. The systems are described in detail and the evaluation is done on both, the process performance and the measurement results achieved. The sixth chapter is related to the software development for automated data evaluation. The challenge was developing a flexible solution, which enables the integration of several analytical measurement instruments from different manufacturers to ensure a fully automated process, including the sample preparation, the measurement, and the final data evaluation. The last chapter is dedicated to the high-level management of automated processes and discusses several management systems used in the field of laboratory automation.

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We wish all users of this book an interesting and informative read.

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Introduction

1.1 Life Sciences – A Definition

1.1.1 A Short Definition of Life

The term life sciences is ubiquitously integrated into our everyday life. It has become a standard expression. To understand the content, challenges, and tendencies of life sciences, it is necessary to define the term life. Today, there exist more than 50 different definitions depending on the scientific field and the strategic focus. In general, life can be defined as a characteristic property, which separates living matter from inorganic matter. The main characteristics include the exchange of matter and energy, reproduction, and growth.

The definition of the term life in philosophy also follows these criteria [1]. Aristotle differentiated three levels of life in a hierarchical order. The lowest level included plants, whose life is characterized only by nutrition and reproduction. The next level included animals, which have the additional features of sensory perception and movement. The human, whose life is, besides the fundamental functions, characterized by thinking processes, is the highest level in Aristotle’s hierarchy.

In the western philosophy of the modern era, two contrary general opinions developed: mechanism [2] and vitalism [3]. Promoters of mechanism explain life processes from the concept of physical laws of movement. The living organism is considered a machine. Main supporters of this idea were William Harvey (1578–1657), Rene Descartes (1596–1650), and Wilhelm Roux (1850–1924). In contrast to this idea, vitalism proposed a significant difference between organic and inorganic matter, whereby life is connected to organic compounds. A targeted living power (vis vitalis) characterizes all living matter. Main supporters of vitalism include Jan Baptist van Helmont (1577–1644), Georg Ernst Stahl (1660–1734), Albrecht von Haller (1708–1777), and Johann Friedrich Blumenbach (1752–1840). Since the synthesis of urea by Friedrich Wöhler (1800–1882), this approach was deprecated, since it could be shown that no special living power is required for the synthesis of organic compounds. A combination of mechanism and vitalism is the organicism [4]. This approach explains processes of life using science principles from physics and chemistry. Living organisms are supposed to have properties that cannot be found in inorganic matter.